

The Evaluation of Spray Drying Process Condition on the Characteristics of Xylitol Powder from Oil Palm Empty Fruit Bunches

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Received: 15th September 2018; 1st Revision: 06th April 2019; 2nd Revision: 24th June 2019; Accepted: 17th March 2020

Abstract

Xylitol is a low-calorie, natural sweetener which has similar sweetness properties to sucrose. Xylitol can be produced from the hemicellulose hydrolysate of Oil Palm Empty Fruit Bunches (OPEFB). Several steps required for this process, including pretreatment, the hydrolysis of xylan to xylose and the reduction of xylose to xylitol. In a commercial market, xylitol is commonly found in the form of powder in order to maintain its distribution stability and practicality. The spray drying method is a drying method that is mostly used in dry or powder products manufacturing industry. This research aims to investigate the effect of spray drying and to determine proper inlet temperature and maltodextrin concentration on xylitol powder characteristics that are similar to the quality of commercially produced xylitol. Randomized Group Design Method is a data processing method used in this research which consisted of two factors: inlet temperature (160 °C and 180 °C) and maltodextrin concentrations (20%, 25%, and 30%). Based on the result of the research, the inlet temperature significantly affected the water content, solubility, hygroscopic levels and calorie content. Results also showed that maltodextrin concentration had a significant effect on the hygroscopic levels, water content and calorie content. Xylitol powder similar to the commercially produced xylitol was obtained from the inlet temperature of 160 °C and 20% of maltodextrin, with the water content of 5.17%, hygroscopic levels of 8.55%, solubility of 99.346%, calorie content of 2.71 cal/g and xylitol content of 0.034 g/L.

Keywords: inlet temperature, maltodextrin, oil palm empty fruit bunch, spray drying, xylitol

INTRODUCTION

Indonesia as one of the largest producers of palm oil has brought a positive impact to the country's economic development. The palm oil industry in Indonesia has contributed 73.69% of the country's economy. In 2002, palm oil consumption in Indonesia had increased significantly from 1.6 tonnes to 4.2 tonnes in 2015, with an average growth of 7.52% per year (Pusdatin, 2016). In 2016, Indonesia had produced 32 million tonnes of palm oil per year. Oil palm empty fruit bunches (OPEFB) as waste from oil palm mill are abundant. The processing of 1 tonne of fresh oil palm bunch will produce around 220-230 kg of OPEFB. The main components of oil palm fruit include 42-51% cellulose, 20-28% hemicellulose and 15-20% lignin (Ariffin et al., 2008; Mardawati et al., 2015). Through the

hydrolysis process, hemicellulose content in OPEFB can be converted into xylose. Subsequently, this xylose can be used as a raw material of xylitol fermentation.

Xylitol is a compound of polyalcohol sugar with five carbon atoms. The sweetness of xylitol is almost equal to sucrose's sweetness, yet it has lower calories, which is 2.4 cal/g (Basuki, 1991; Mardawati et al., 2015). The most common technique used in xylitol production is the xylose hydrogenation technique. This technique requires high costs and pure xylose as its raw material (Soleimani, Tabil, & Panigrahi, 2006). As xylitol is highly needed in the food, chemical and pharmaceutical industry, it is necessary to find an alternative to cheaper xylitol production method (Dominguez, Gong & Tsao, 1997). The characteristics of xylitol in compliance with xylitol

quality standards are listed in Table 1 and Table 2.

One of the alternative methods to produce affordable xylitol is by performing a fermentation process using microorganisms. Tested yeast that can be used to produce xylitol is *Debaryomyces hansenii* (Mardawati et al., 2015; Ambarsari et al., 2014; Winkelhausen & Kuzmanova, 1998). An advantage of the xylitol bioprocess is the utilization of hydrolysate containing xylose obtained from the hydraulic process of lingocellulose. One of those biomass materials is OPEFB.

Xylitol production from OPEFB consists of several stages that is raw material pre-treatment, OPEFB hydrolysis producing xylose hydrolysate, xylose fermentation to xylitol and purification of fermented xylitol. The purification process and downstream processing of xylitol solution are required to produce powder xylitol so that xylitol can be stored longer and also to ease the distribution process.

Table 1. Xylitol quality standard

Characteristic	Description
Chemical Name	Xylitol
Chemical Formula	C ₅ H ₁₂ O ₅
Molecular Weight	152.15
Color	White
Form	Powder
Smell	Odorless
Solubility	Very soluble in the water, slightly soluble in ethanol
Melting Point	92-96 °C
Purity	Water: less than 0.5% (Karl Fischer method)

Source: (FAO, 1996)

Table 2. Xylitol physical characteristic

Characteristic	Description
Molecular Weight	152.15 g/mol
Form	White crystalline powder
Smell	Odorless
pH in the water (1 g/ 10 mL)	5 – 7
Boiling Point	126 °C
Melting Point	92 °C – 95 °C
Solubility at 20 °C	169 g in 100 g of water, slightly soluble in ethanol and methanol
Heat of Solution	-34.8 cal/g
Calorie Value	2.4 kal/g

Source: (FAO, 1996)

Generally, any xylitol sold in the market is in the form of dry product. There are several types of the drying process; one of those processes is spray drying. According to Masters (2004), spray drying is one of the most used drying methods in the industry because of its effectiveness in producing dry products, considering its short drying time. The final product is also more durable due to reduced water content so that the possibility of any damage caused by microbes or chemicals is minimized. The spray drying method is basically about the fluid atomization process to form droplets, in which those formed droplets will then be dried with hot air at certain temperature and pressure (Singh & Heldman, 2001).

Factors impacting the spray drying process include inlet air temperature, material feed rate, air discharge of dryer, humidity and environment temperature. Internal factors in the spray drying process include material properties, material types and coating material used. According to Gharsallaoui et al. (2007), some types of coating that are commonly used include coating made from gum, protein and carbohydrate.

According to Chen & Mujumdar (2008), drying air temperature for food is ranging from 150 – 270 °C. According to Estiasih & Ahmadi (2009), significant temperature difference between material and heating medium cause faster heat movement. This condition leads to faster water evaporation of materials, which then causes faster drying time. Besides, dryer air temperature affects the water content where the lower water content level, the lower yield produced and the production efficiency will increase. Meanwhile, maltodextrin gives impacts on solubility levels and drying time. Therefore, this research was performed to determine the proper inlet temperature and maltodextrin concentration to produce xylitol powder with similar characteristics to the xylitol quality standard. It is also aimed to investigate the impact of inlet temperature and maltodextrin addition on the characteristics of xylitol powder.

METHODS

Material used in the research was OPEFB obtained from PTPN VIII Bogor, maltodextrin DE 12 from Subur Kimia Jaya Bandung, distilled water, GYE (Glucose-Yeast Extract) media, and xylanase enzyme obtained from Xi'an Haoxuan Bio-tech Co., Ltd Company of Xian City, China Shanxi province, *Debaromycess hansenii* yeast

from Bandung Institute of Technology, active carbon and acetate buffer. Instruments used for this research are High Performance Liquid Chromatography (HPLC), EYELA SD-1000 spray dryer, oven, autoclave, IKA KS4000 incubator shaker, Whatman No 1 membrane filters and other glassware.

The method used in this research was an experimental method with Randomized Group Design (RGD) for data processing and three (3) times repetition. Tested experimental design included: Factor 1, i.e. inlet temperature (t_1 : 160 °C dan t_2 : 180 °C), and Factor 2, i.e. maltodextrin concentration (m_1 : 20%, m_2 : 25% and m_3 : 30%). The observation result was then statistically analyzed with Anova. If a real impact is observed in the experiment, then Duncan's Multiple Range Test shall be performed at the real levels of 5%. The experiment step consisted of material preparation, hydrolysis of oil palm empty fruit bunch, OPEFB hydrolysate fermentation and xylitol powder preparation using spray drying.

Materials Preparation

The materials were prepared by reducing OPEFB's size into OPEFB flour. The size reduction procedure refers to the previous research conducted by Mardawati et al. (2017). OPEFB was cleaned under running water and then the size reduction process was performed by cutting OPEFB with a knife. Cut OPEFBs were then dried in the oven at the temperature of 60 °C for 24 hours. Dry OPEFB was mashed up with the disc mill and then sifted with 60 mesh sieve to obtain particles with relatively uniform size (Mardawati et al., 2018).

Hydrolysis of Oil Palm Empty Fruit Bunch (OPEFB)

The process of OPEFB hydrolysate preparation was initiated with measuring 15 grams of OPEFB flour and dissolving it with 100 mL of pH 5 acetate buffer and then mixing it in Erlenmeyer flask. Next, 10% xylanase enzyme at the optimum temperature of 45-50 °C and pH 5 was added. The incubation was conducted in the incubator shaker at the temperature of 50 °C for 96 hours. OPEFB hydrolysate created with solids was then centrifuged at a speed of 6,000 rpm for around 20 minutes and the OPEFB hydrolysate was produced (Mardawati et al., 2018).

OPEFB Hydrolysate Fermentation

Oil palm empty fruit bunch hydrolysate fer-

mentation consisted of three stages: (1) yeast cell rejuvenation of *Debaromyces hasenii*, (2) inoculum creation and (3) fermentation according to (Mardawati et al., 2015). Fermentation process was initiated by creating fermentation media and the inoculation process. The sugar solution used was OPEFB hydrolysate containing xylose. The hydrolysate was fermented with the addition of inoculum and fermentation medium solution under aerobic condition, at pH 5, the temperature of 30 °C and a speed of 200 rpm (Mardawati et al., 2015). The ratio between hydrolysate: inoculum solution: medium were 2 : 2 : 3. Then, the fermentation solution was purified by adding 15 g/L of active carbon and then filtered by using a vacuum filter.

Spray Drying Process in Producing Xylitol Powder

Xylitol residue of the purification was then going through the drying process by using spray dryer to produce xylitol powder. The material used for coating was Maltodextrin at the concentration of 20%, 25% and 30%. In this stage, the mixing process was performed by using a homogenizer for around 30 minutes at a speed of 10,000 rpm. Xylitol solution with the addition of maltodextrin was then placed in the spray dryer at the inlet temperature of 160 °C and 180 °C and the outlet temperature of 90 °C. Then, several analysis processes were performed encompassing water content, hygroscopic, solubility, and calorie content and xylitol content analysis.

RESULTS AND DISCUSSION

The result of xylitol powder production from oil palm empty fruit bunch using spray drying method can be seen in Table 3.

Water Content

Water content is the main parameter in determining the quality of dry products. Xylitol's water content resulted from this research was lower in value. Xylitol water content resulted from this research was ranging from 3.63-5.17%. It is in line with Reineccius' (2004) statement, where the water content obtained from spray drying was 2-6%. The result of the xylitol water content analysis of the spray dryer can be seen in Table 4.

Table 4 shows that the inlet temperature of 160 °C is significantly different from the inlet temperature of 180 °C on the water content of

Table 3. Analysis of the result on the water content, hygroscopic, solubility, calorie content and xylitol content

Description	Research Results					
Inlet temperature (°C)	160			180		
Maltodextrin Concentration (%)	20	25	30	20	25	30
Water Content (%)	5.17	4.40	4.59	4.43	3.63	3.67
Hygroscopic level (%)	8.55	8.56	7.41	7.73	7.52	6.34
Solubility (%)	99.34	99.44	99.58	99.67	99.67	99.72
Calorie Content (cal/g)	2.71	2.73	2.75	2.72	2.76	2.80
Residual Glucose (g/L)	0.144	0.332	0.209	0.241	0.292	0.300
Residual Xylose (g/L)	0.192	0.519	0.314	0.306	0.370	0.462
Xylitol Concentration (g/L)	0.034	-	-	-	0.079	0.079
Yield (g/g) (P _{p/s})	0.023	-	-	-	0.054	0.054

Table 4. Effect of inlet temperature and maltodextrin concentration on water content

Treatment	Average Percentage of Water Content (%)
Inlet temperature (°C)	
160	4.72 ^b
180	3.91 ^a
Maltodextrin (%)	Average Percentage of Water Content (%)
20	
25	
30	

xylitol powder and maltodextrin concentration of 20% is different from the water content of xylitol powder with the concentration at 25% and 30%. However, maltodextrin concentration of 25% is not much different from 20% and 30% of maltodextrin concentration. According to Tonon, Brabet, & Hubinger (2008), in high inlet temperature, there is a high heat gradient between atomized feed and drying air, which resulted in faster evaporation in sprayed materials so that it produces powder with low water content. According to Maulina, Rosarrah, & Djaeni (2013), in high inlet temperature, the humidity is also low so that the heat and mass transfer between air and solution will be high. This condition leads to low water content produced by the material. In general, the addition of maltodextrin as coating material will increase the total solids of dried material, yet the amount of evaporated air will be low so that maltodextrin concentration increases will reduce the water content of xylitol powder. According to Masters (2004), the higher total solids dried under a certain limit, the faster evaporation speed will be. As a result, the water content of the material will be low. Based on xylitol quality standard, maximum water content required to meet the quality standard is 5%.

Hygroscopic Levels

Hygroscopic analysis of high hygroscopic

characteristic products has an impact on quality reduction (Canuto, Afonso, & Costa, 2014). According to Hyvonen & Koivistoinen (1982), xylitol equilibrium water content is categorized as low when the value is under 80% RH and high when the value is above 80% RH. The result of xylitol hygroscopic analysis produced in this research was 6.34 – 8.56%. The analysis of hygroscopic levels of xylitol powder showed that inlet temperature and maltodextrin concentration significantly affected the hygroscopic levels of powder xylitol produced. Analysis of the result of hygroscopic levels can be seen in Table 5.

Based on Table 5, the process of xylitol powder production at the inlet temperature of 160 °C is different from the spray dryer at the temperature of 180 °C. Meanwhile, the addition of 30% of maltodextrin concentration is significantly different from the addition of 25% and 20% maltodextrin concentration. Increasing maltodextrin concentration that used as the coating has decreased the hygroscopic of xylitol powder. It follows the result of Canuto et al. (2014) which reported that maltodextrin as an encapsulant in freeze-dried papaya porridge had decreased product's hygroscopic. Therefore, the product's stability would improve. In the iso-thermic curve, in line with increased maltodextrin concentration in the same water activity (Aw) condition, the highest maltodextrin concentration will reach

Table 5. Effect of inlet temperature and maltodextrin concentration on hygroscopic

Treatment	
Inlet temperature (°C)	Average Percentage of Hygroscopic Levels (%)
160	8.17 ^b
180	7.20 ^a
Maltodextrin (%)	
20	8.14 ^c
25	8.04 ^{bc}
30	6.86 ^a

Table 6. Effect of inlet temperature and maltodextrin concentration on solubility

Treatment	
Inlet temperature (°C)	Average Percentage of Solubility (%)
160	99.46 ^a
180	99.69 ^a
Maltodextrin (%)	
20	99.51 ^a
25	99.56 ^a
30	99.65 ^b

equilibrium moisture (X_{eq}) in a low value (Canuto et al., 2014). Low DE will generate non-hygroscopic, easily retrograde maltodextrin. However, too high DE will generate high glucose content, so that it will absorb water easily (hygroscopic) and the texture will be sticky because of its hygroscopic characteristics.

Inlet temperature gives a real impact on the hygroscopic of xylitol powder. According to Tonon et al. (2008), the effect of inlet temperature (140, 170, 200 °C) where the powder produced in higher inlet temperature will be more hygroscopic because of the water content contained in the powder. Higher drying temperature will decrease water content and increase its hygroscopic levels. This is due to the high water concentration gradient between the product and surrounding air that generates less humid powder.

Solubility

Solubility is a crucial parameter in powder product which tested material ability to dissolve in the water. The solubility value of xylitol powder produced in this research was ranging from 99.357-99.722%. Based on the data obtained, it can be seen that the solubility of resulted xylitol powder was affected by the water content. Low water content powder will dissolve easily (Goula & Adamopoulos, 2008), which is indicated by high solubility value. The result of variance analysis showed that inlet temperature and maltodextrin concentration have a real impact on xylitol powder solubility. The result of the

analysis of xylitol powder solubility can be seen in Table 6.

Based on Table 6, solubility obtained at inlet temperature treatment of 160 °C is significantly different from solubility obtained at an inlet temperature of 180 °C. Also, the addition of 30% maltodextrin is significantly different from the addition of 25% maltodextrin. Meanwhile, the addition of 20% maltodextrin is not quite different from the addition of 25% maltodextrin. The solubility value of xylitol powder produced is in line with the water content as solubility is affected by the water content. If the water content of powder is low, the powder will be easily dissolved (Goula & Adamopoulos, 2008). Xylitol powder solubility is affected by the addition of maltodextrin. The higher the maltodextrin concentration, the higher the solubility levels of the xylitol powder. According to Chuaychan and Benjakul (2016), maltodextrin is hydrophilic so that it can increase the solubility. The solubility of xylitol produced in this research is almost similar to the standard xylitol solubility.

Solubility is also affected by the inlet temperature, where high inlet temperature will increase the solubility value of the material. It is due to the effect of inlet temperature on the water content of the material. Low water content has caused this material to dissolve easily. An increase in inlet temperature resulted in increased particle size and decreased dissolution time of the material. Low water content and high solubility levels result in better quality products (Hardijanti

Table 7. Effect of inlet temperature and maltodextrin concentration on calorie content

No	Treatment	Maltodextrin Concentration (%)		
	Temperature (°C)	20	25	30
1.	160	a 2.71 ^A	a 2.73 ^A	a 2.75 ^A
2.	180	a 2.72 ^A	a 2.76 ^{AB}	a 2.80 ^B

Description: Any number followed by the same letter in each row and column shows that there is no real difference at 5% level. Lowercase letters are read horizontally and uppercase letters are read vertically.

2008).

Calorie Content

The calorie content is one of the xylitol advantages as a sugar source, which is lower than sucrose sugar calorie that can be consumed regularly. Based on the results, the calorie content of xylitol powder produced from the research is between 2.71-2.80 cal/g. According to Ly, Milgrom & Rothen (2006), the calorie content of xylitol is 2.40 cal/g, where xylitol calorie content is lower than the calorie content of sugar, that is 4 cal/g. The calorie value of xylitol powder produced is higher than commercial xylitol but lower than the calorie content of sucrose that is 4 cal/g. The analysis of the result on variation in xylitol powder calorie content can be seen in Table 7.

Hui (2006) stated that maltodextrin is a good ingredient to add in food since it has several characteristics such as high solubility, fast disparity process, the ability to form a film, low hygroscopic, the ability to inhibit crystallization and the ability to be used in a low-calorie food as its calorie is only 1 cal/g. The calorie value of a substance is affected by bound carbon content, water content and ash content. The higher water content will decrease the calorific value of a substance (Hendra, 2011). Water content also affects the calorific value of a material in calorimeter, where the water is a medium for tested heat release. If the water content of a certain substance is high, then the energy needed for drying and combusting process is also high. The calorific value of substance combustion depends on its chemical composition and water content. The lower water content, the higher the heating value of the combustion (Aina, Adetogun, & Iyiola, 2009). The calorie content of xylitol resulted from this OPEFB is relatively high if it is compared with commercially produced xylitol, where the standard calorie content is 2.4 cal/g.

Xylitol Content

Xylitol powder is dissolved in the distilled water to analyze its xylitol content by using HPLC. Based on the analysis of the result, xylitol

powder contains several components such as xylitol, glucose and xylose. An additional component, like glucose and xylose are also called residual sugar. Glucose and xylose components can affect the characteristics of xylitol powder, such as its melting point, calorie content and hygroscopic levels. Residual sugar exists as a result of the less optimum purification process of the fermentation solution. Besides, the addition of an extraneous substance, i.e. maltodextrin, in the mixture will also result in residual sugar. Maltodextrin is a product of the starch hydrolysis containing α -D-glucose where most of the glucose are bound with 1,4 glycosidic bond. Maltodextrin consists of the mixture of glucose, maltose, oligosaccharides and dextrin (Srihari et al., 2010).

Based on Table 3, powder produced at the temperature of 160 °C with 20% of maltodextrin concentration will produce 0.0343 g/L xylitol with 0.0233 g/g of yield. Sample with the temperature of 180 °C and the addition of 25% of maltodextrin will produce 0.0790 g/L xylitol with 0.0536 g/g yield. Sample with the temperature of 180 °C and the addition of 30% of maltodextrin will produce 0.0798 g/L xylitol with 0.0542 g/g yield. In Mardawati et al. (2018) research, hydrolysate fermentation will produce xylitol content as many as 0.138 g/L. Compared to the xylitol quality standard with maximum purification level, the xylitol purification level from this OPEFB is relatively low.

Some factors inhibiting fermentation in the xylitol production process include temperature, pH, aeration, substrate concentration and other types of sugar such as xylose and glucose (Ambarsari et al., 2014). The formation of xylitol is caused by microbes consuming xylitol (Mardawati et al., 2018). Besides, higher glucose content in the fermentation solution results in inhibited xylose transportation to the cell that can decrease xylitol production (Tochampa et al., 2005).

According to Sutrisno & Susanto (2014), sugar content in a product can be affected by the heating process. This can occur as there is a

decrease in water content so that the percentage of sugar content will increase. This condition is also supported by the statement of Sugiyono (2012), which mentioned that water evaporation during the heating process would decrease water content and solids concentration will increase. Quek, Chok, & Swedlund (2007) in his research, stated that maltodextrin addition in the water-melon drying process using spray dryer proved that the sugar content produced is decreasing. This condition might be resulted from caramelization reaction.

CONCLUSION

The research on xylitol powder production using a spray dryer was performed. Inlet temperature and maltodextrin concentration were found to affect water content, hygroscopic, solubility and calorie content. The interaction of inlet temperature and maltodextrin concentration has a significant effect on the calorie content of xylitol powder. Xylitol powder that is similar to xylitol quality standard obtained in the inlet temperature of 160 °C and 20% of maltodextrin concentration. From this condition, xylitol powder produced from the research has several characteristics such as 5.17% of water content, 8.55% of hygroscopic level, 99.34% of solubility and calorie content as many as 2.71 cal/g with 0.034 g/L xylitol content.

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